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FIG. 1

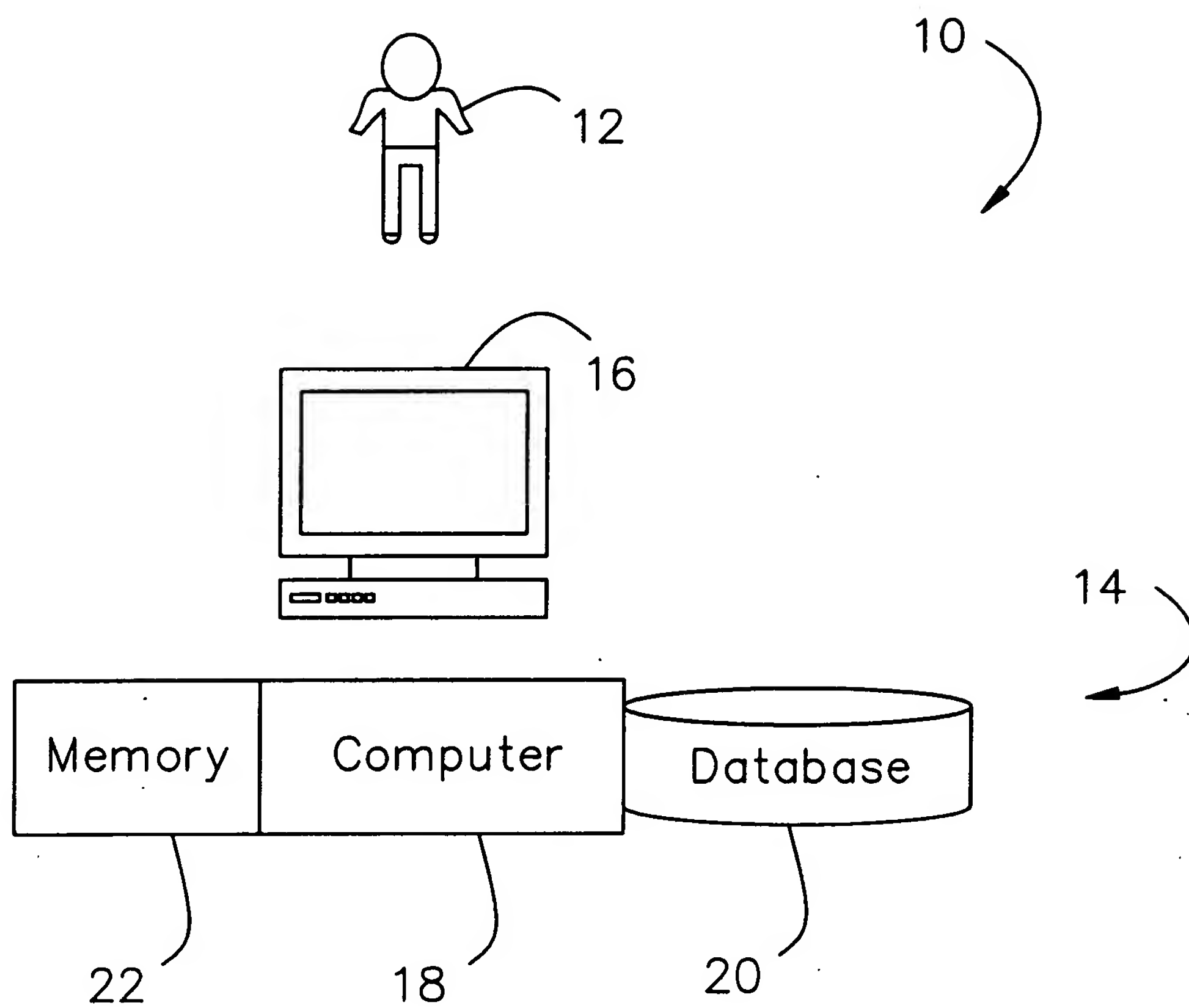


FIG. 2

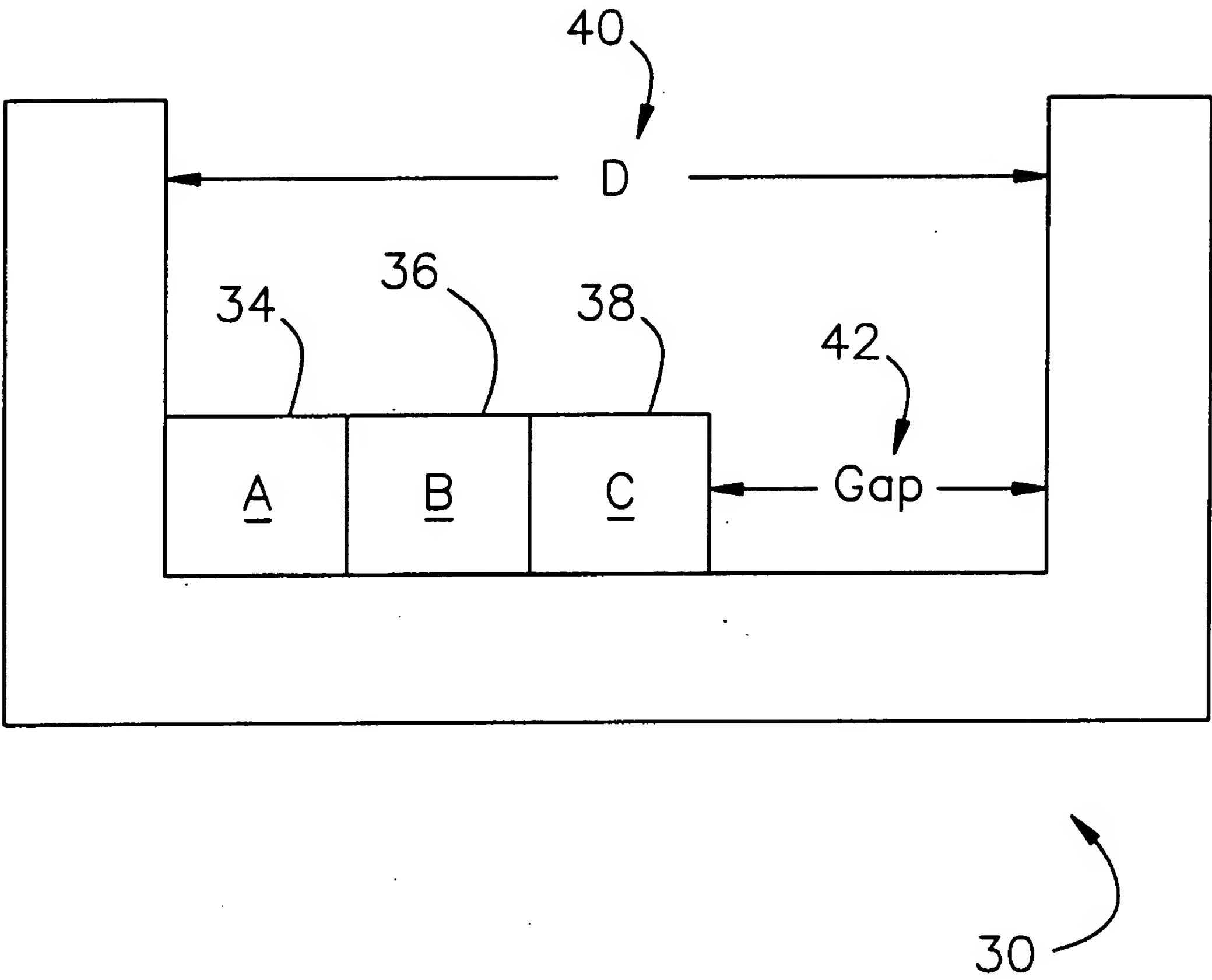


FIG. 3A

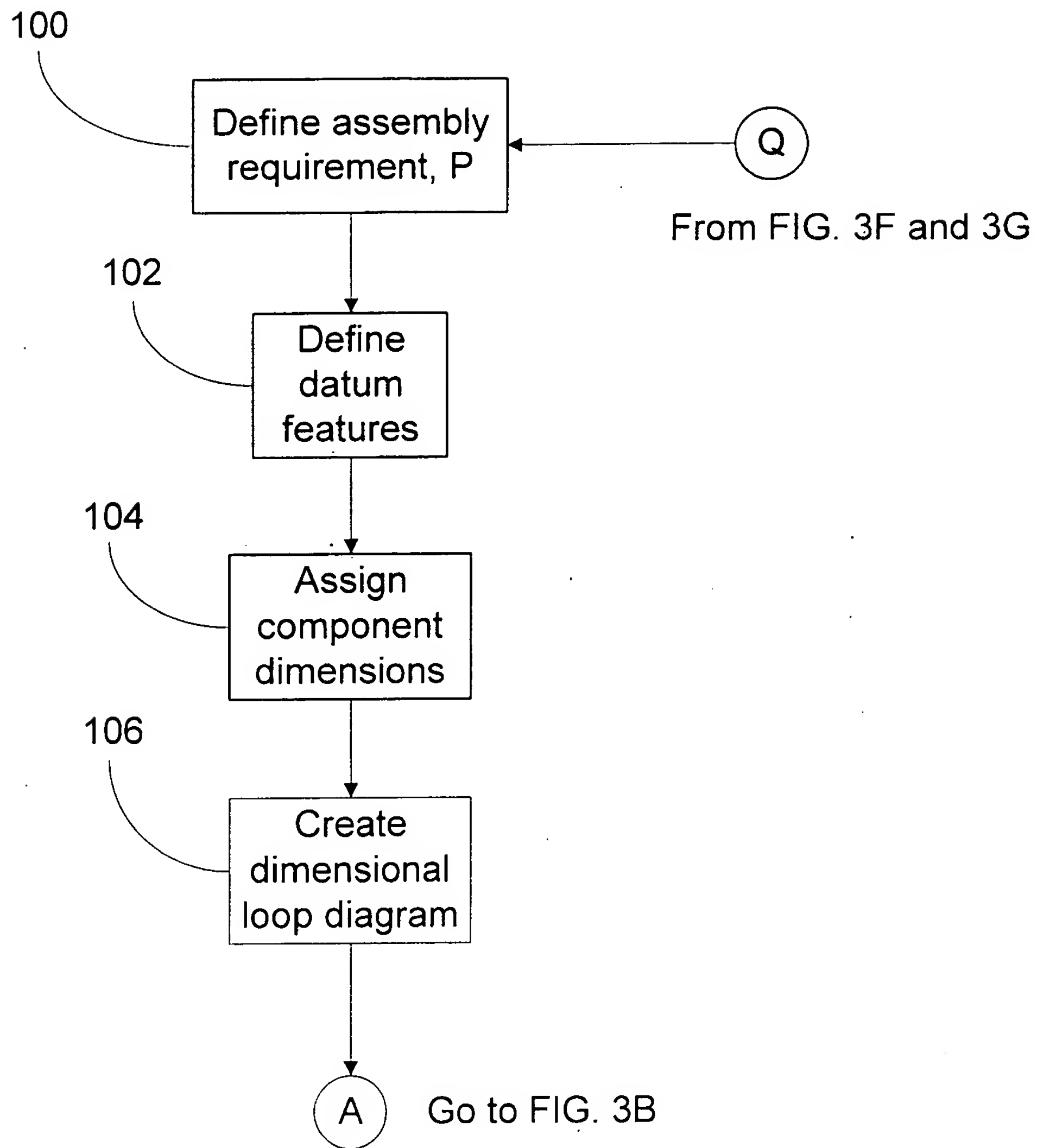


FIG. 3B

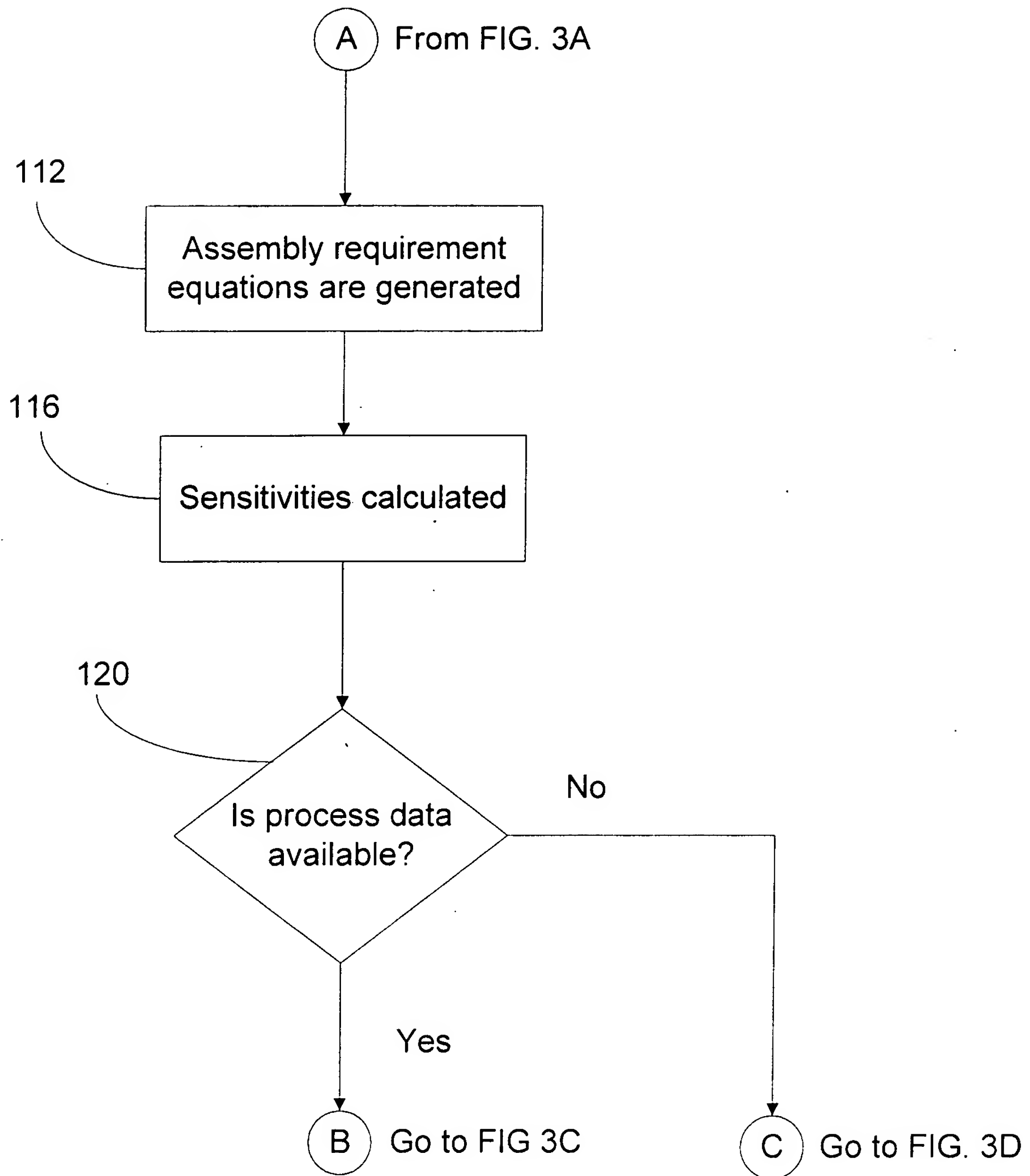


FIG. 3C

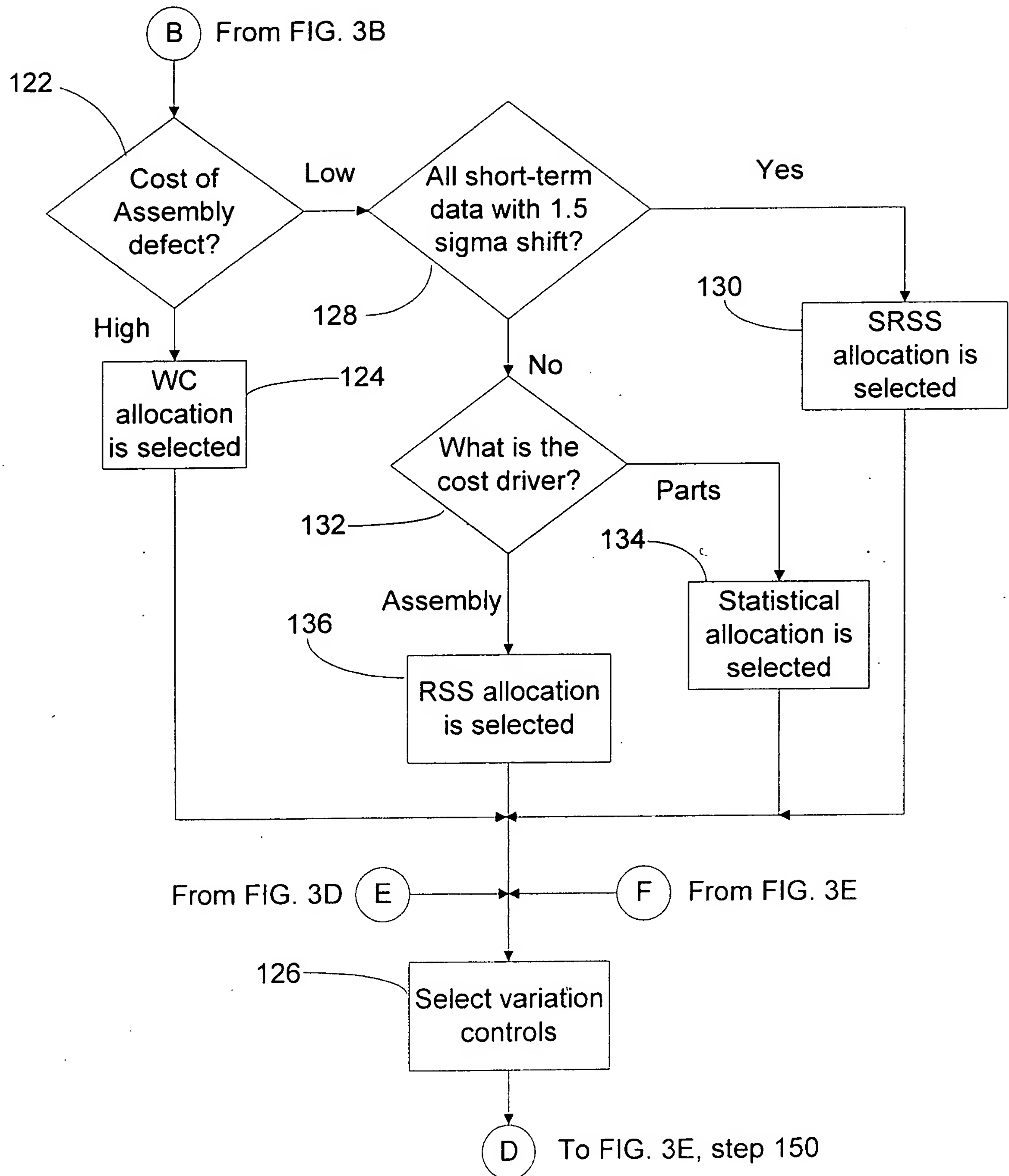


FIG. 3D

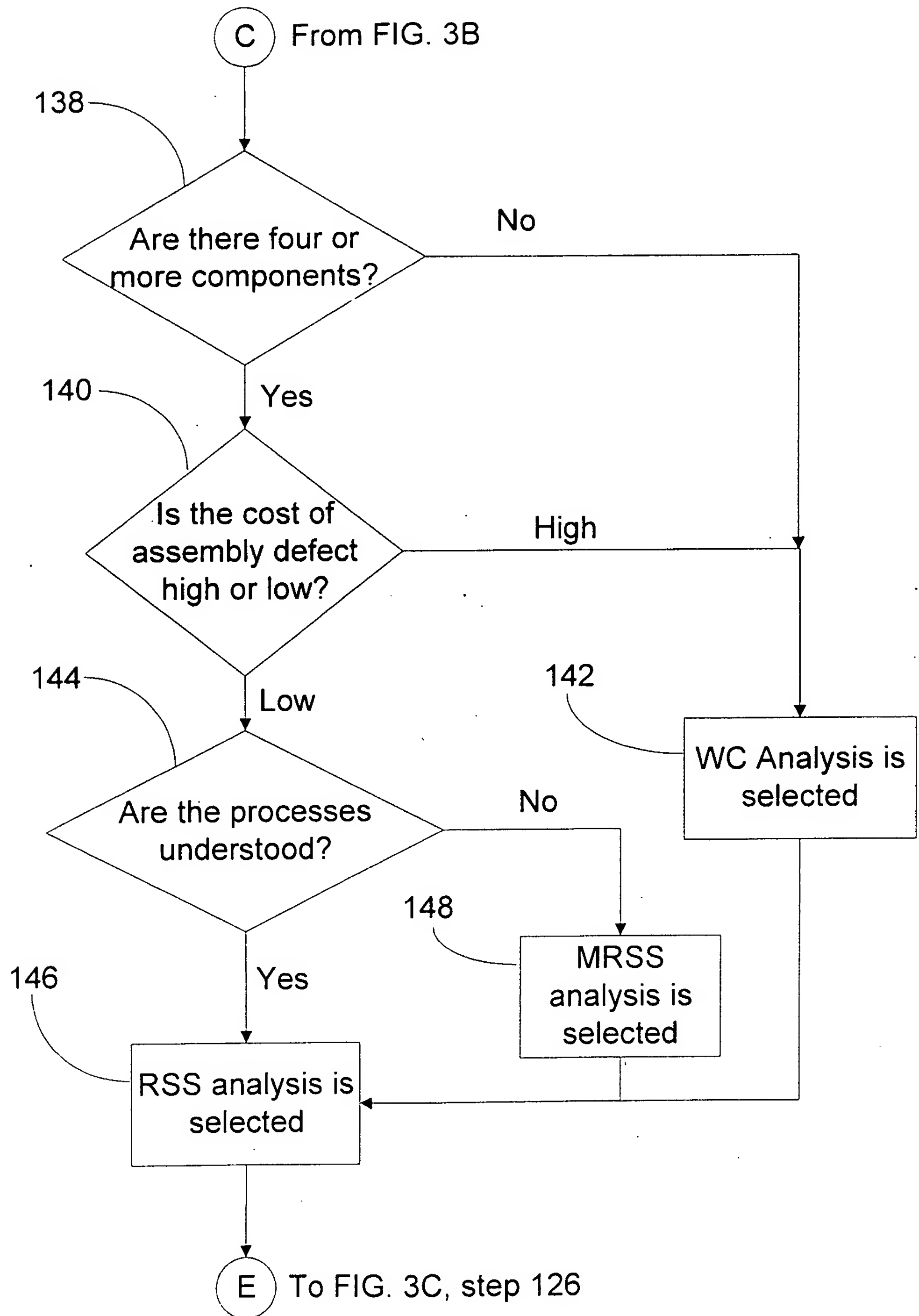


FIG. 3E

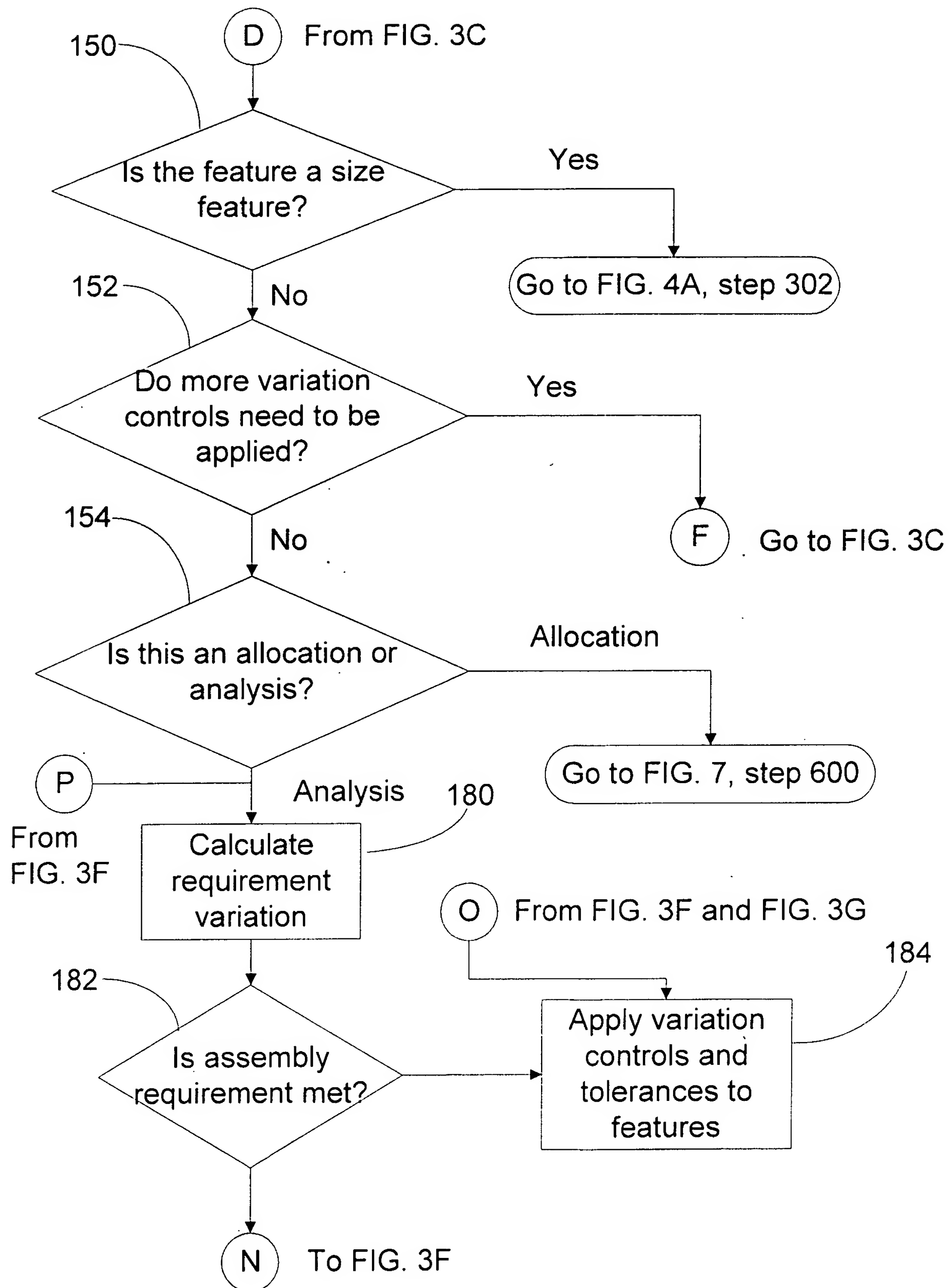


FIG. 3F

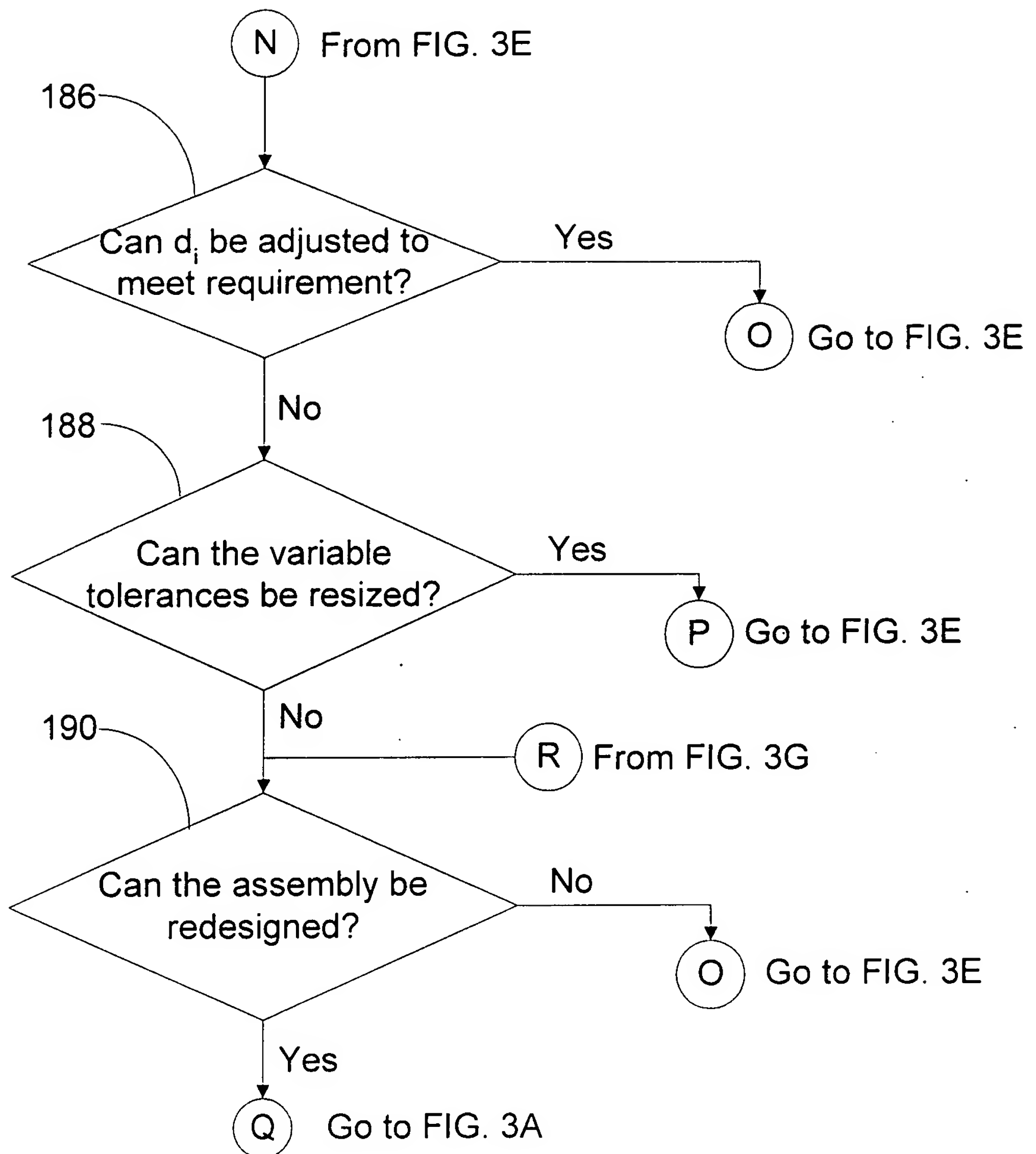


FIG. 3G

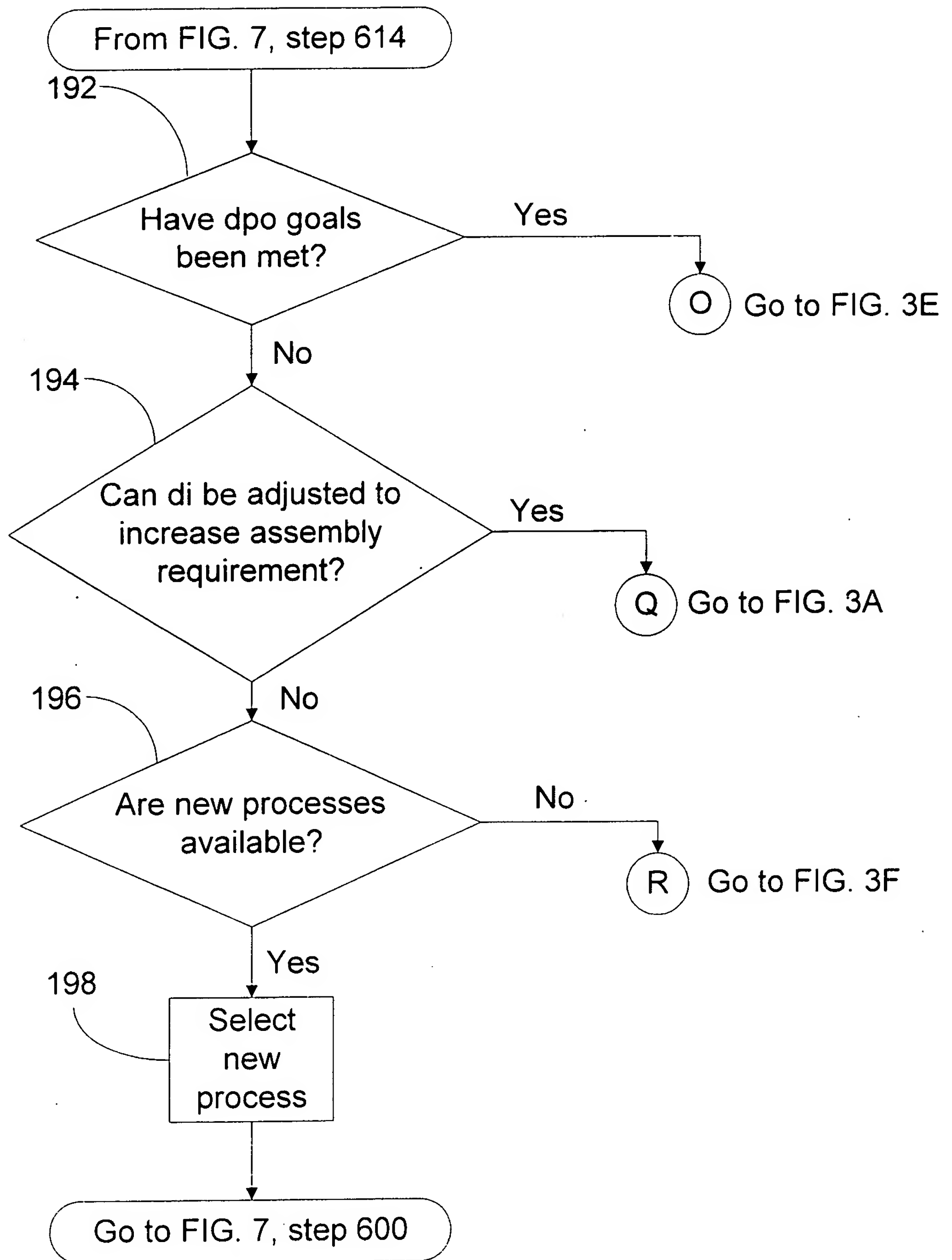


FIG. 4A

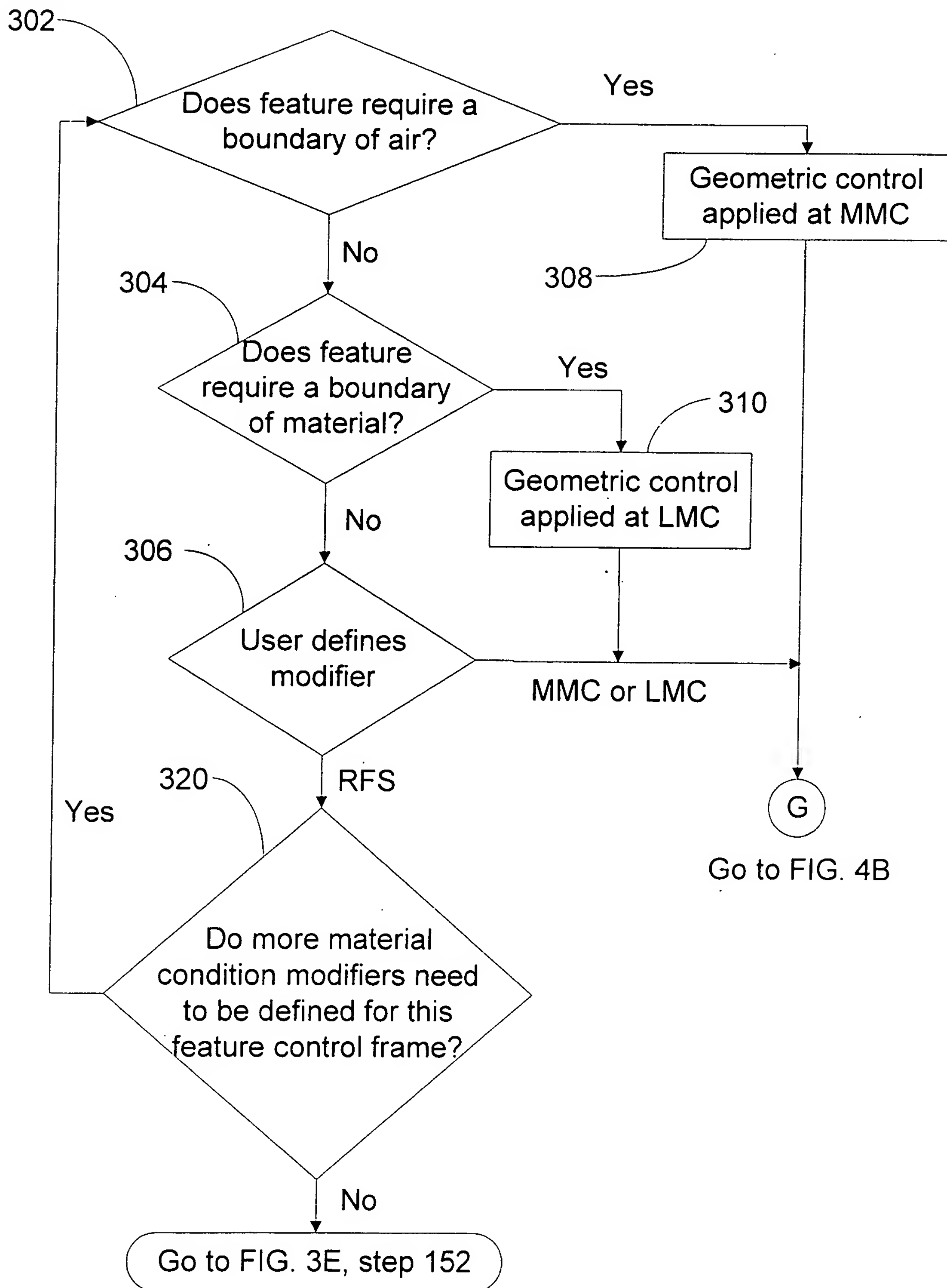


FIG. 4B

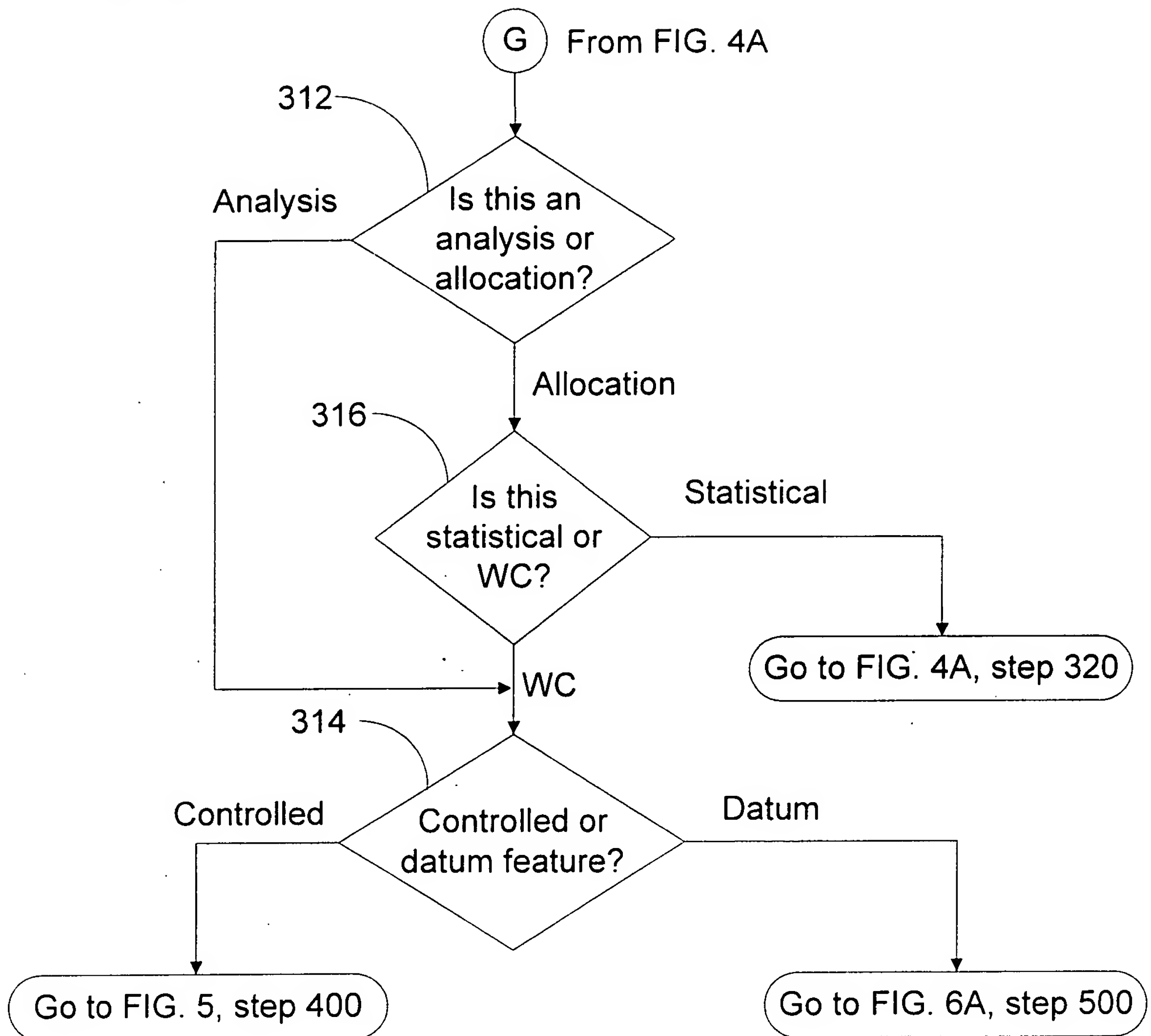


FIG. 5

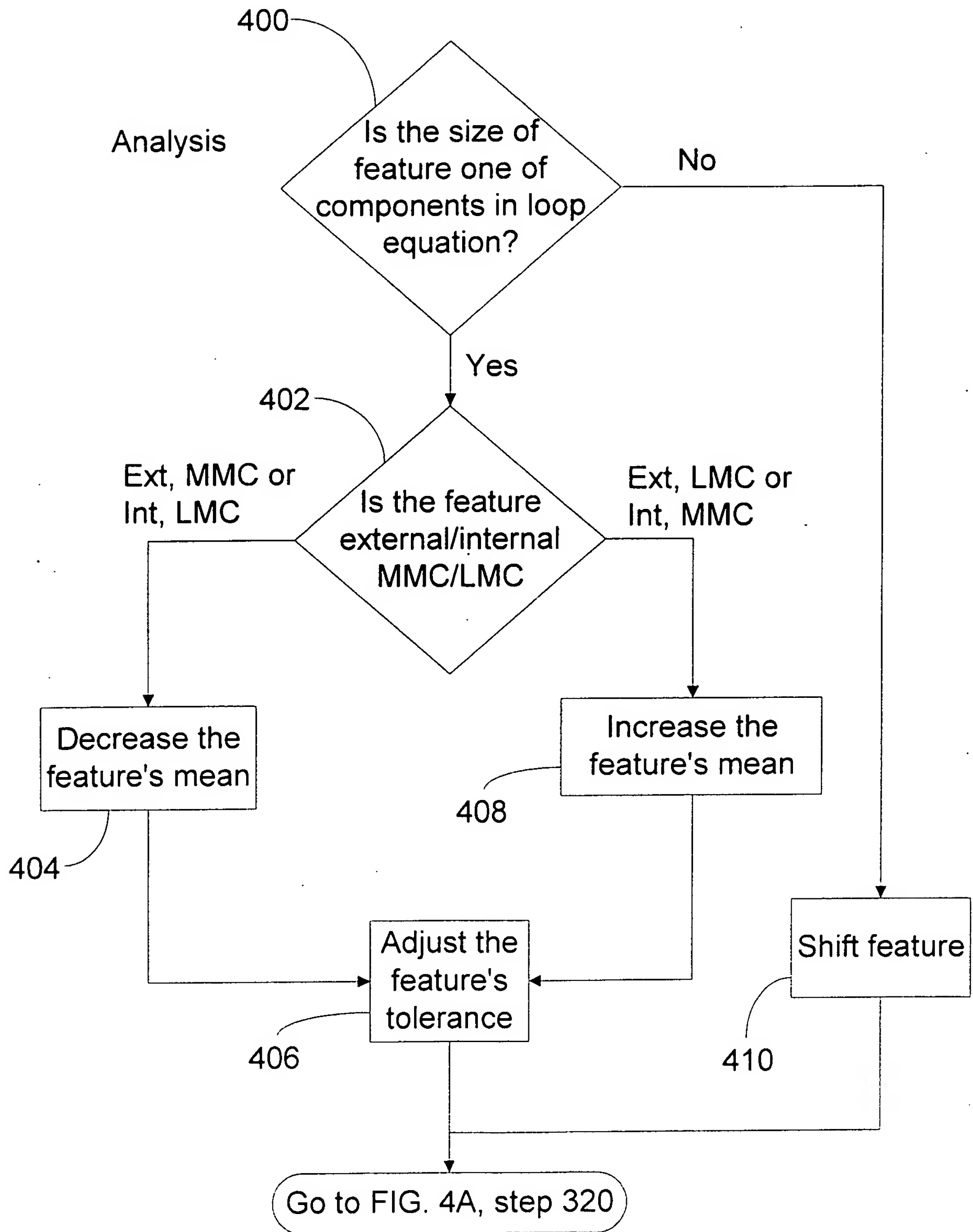


FIG. 6A

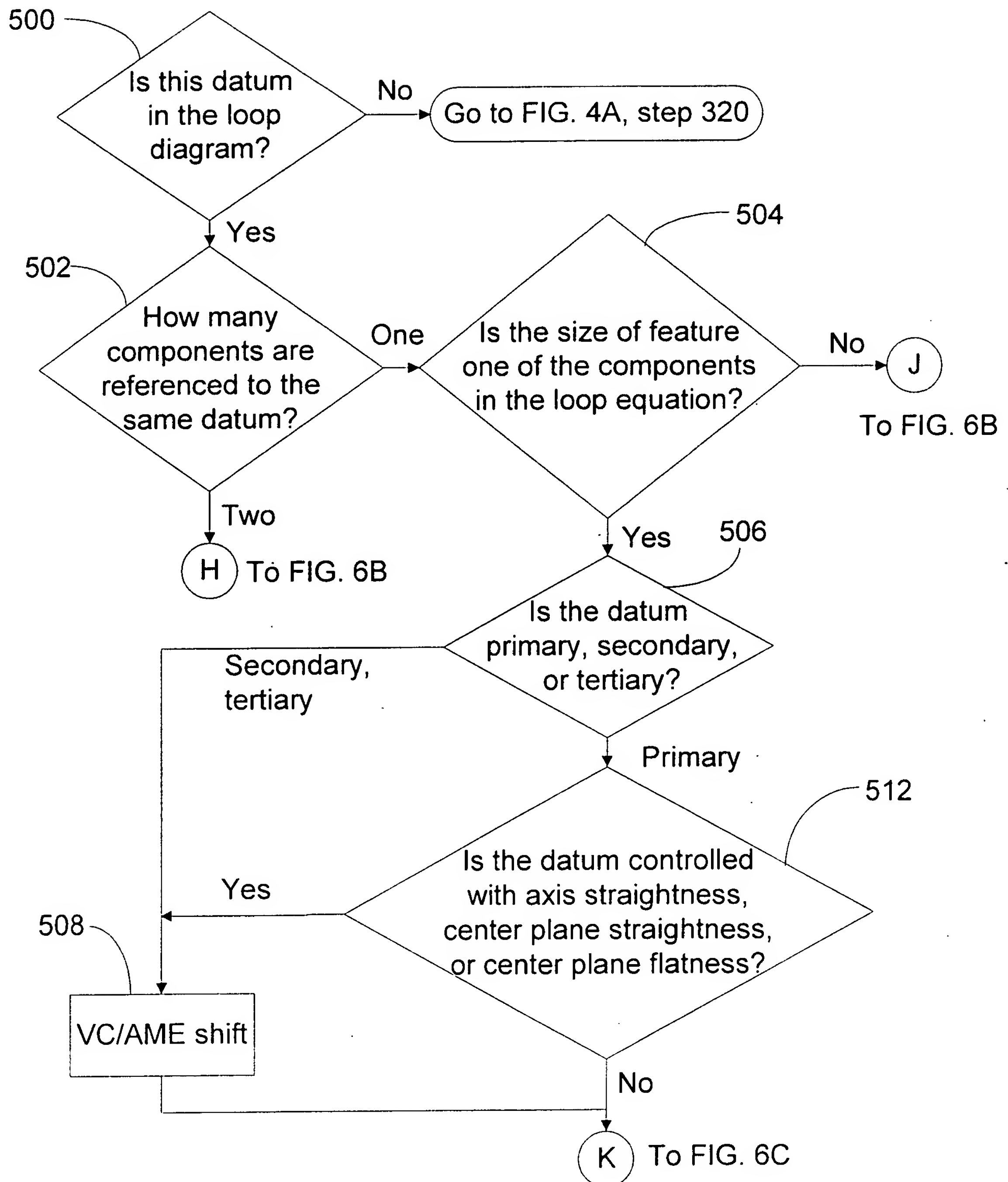


FIG. 6B

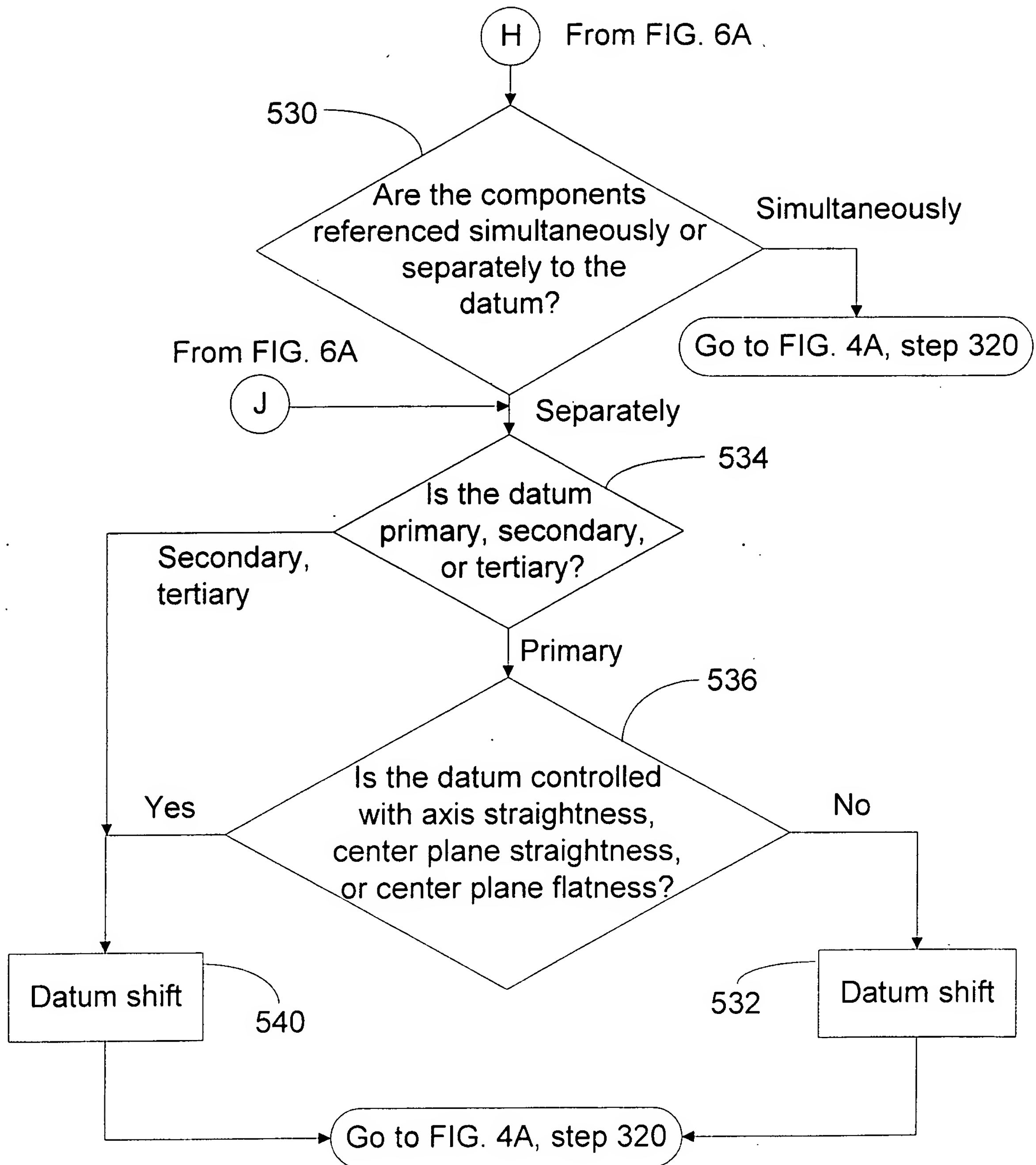


FIG. 6C

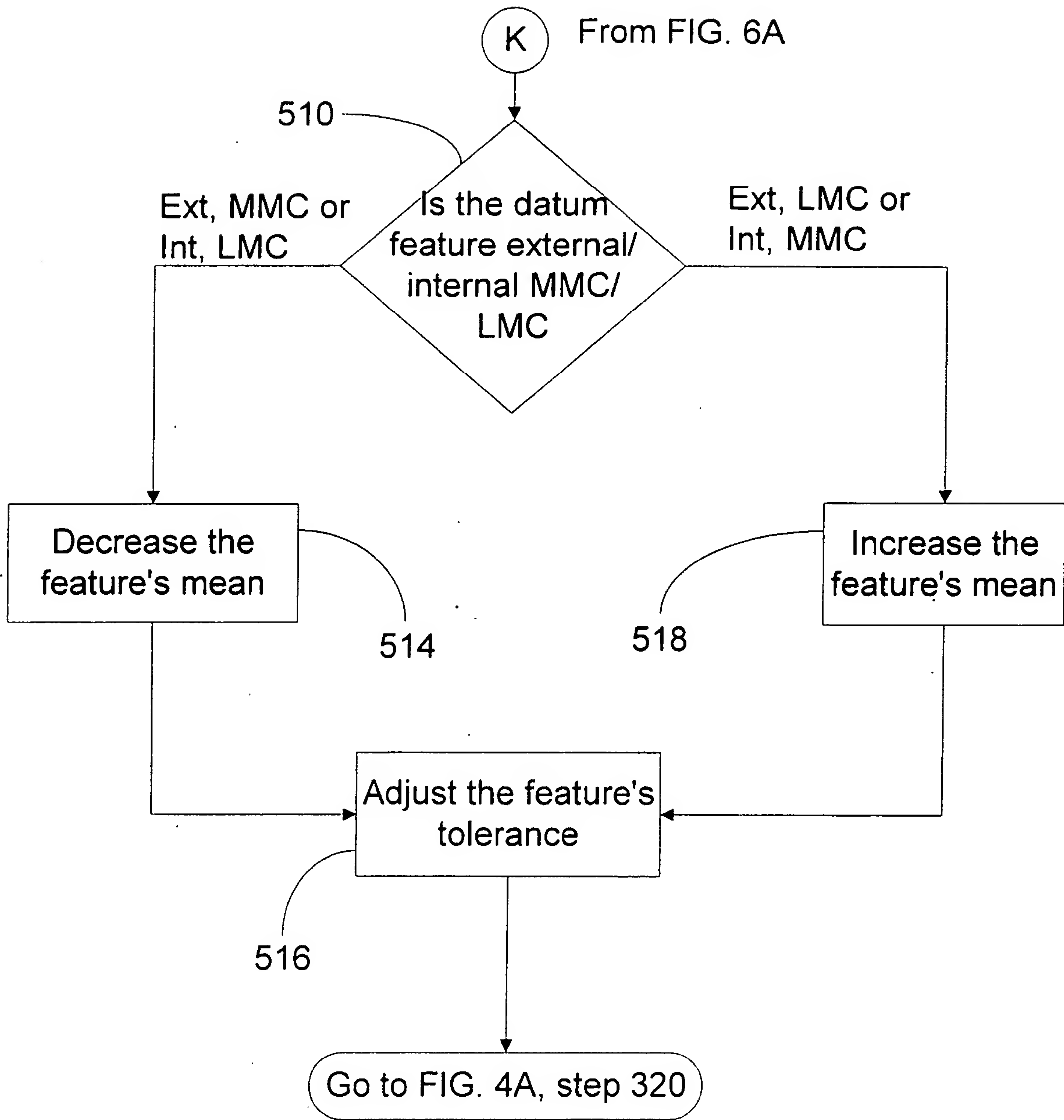


FIG. 7

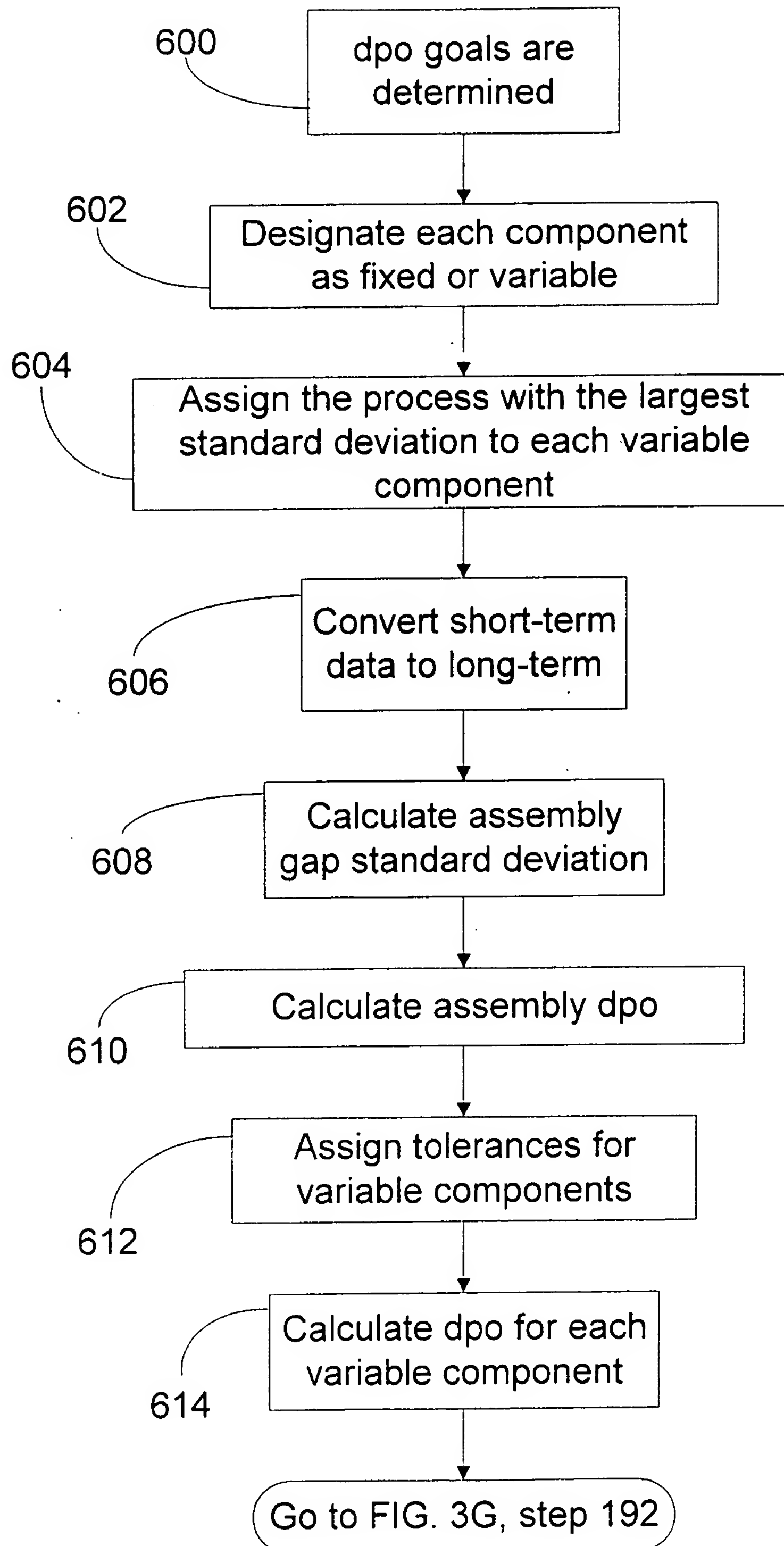


FIG. 8

FIG. 8.1	FIG. 8.6	FIG. 8.11	FIG. 8.16	FIG. 8.21
FIG. 8.2	FIG. 8.7	FIG. 8.12	FIG. 8.17	FIG. 8.22
FIG. 8.3	FIG. 8.8	FIG. 8.13	FIG. 8.18	FIG. 8.23
FIG. 8.4	FIG. 8.9	FIG. 8.14	FIG. 8.19	FIG. 8.24
FIG. 8.5	FIG. 8.10	FIG. 8.15	FIG. 8.20	FIG. 8.25

"Feature" Type	Controlled Element of Feature	Tolerance Zone Shape
Planar	Independent line elements of surface	Parallel lines
	Single surface	Parallel planes
		Wedge
	More than one surface	Parallel planes

FIG. 8.1

Conical	Two opposed points	Width
	Line element of surface	Parallel lines
	Circular elements of surface	Concentric circles
	Entire surface	Equidistant Profiles
Radial	Radial line elements of a surface	Concentric arcs (lines)
	Entire surface (flats and reversals allowed)	Min/max radius arc
		Concentric arcs (contours)
	Entire surface (no flats or reversals allowed)	Min/max radius arc
		Concentric arcs
Cylindrical	Two opposed points	Width

FIG. 8.2

	Line element(s) of a surface	Parallel lines
	Circular elements of surface	Concentric circles
	Entire surface	MMC boundary and LMC size width
		Concentric cylinders
Axis	Derived median points	Cylinder
	Derived median line	Cylinder
	Axis of actual mating envelope	Parallel planes
		Cylinder

FIG. 8.3

Width	Two opposed points	Width
	Two opposed lines	MMC boundary and LMC size width
	Two opposed planes	MMC boundary and LMC size width
	Two angled surfaces	Wedge
Center plane	Derived median line	Parallel lines
	Derived median plane	Parallel planes
	Center plane of actual mating envelope	
Revolute (that is not cylindrical or conical)	Two opposed points	Width
	Circular elements of surface	Concentric circles
	Line elements of surface	Equidistant 2-D boundaries

FIG. 8.4

	Entire surface	Equidistant 3-D boundaries
Spherical	Two opposed points	Width
	Entire surface	MMC boundary with LMC size width
		Concentric spheres
Point	Derived median points	Spherical diameter
	Center point of actual mating envelope	
Surfaces	Independent surface cross sections	Equidistant, 2-D boundaries
	Entire surface	Equisistant cross sectional profiles
		Equidistant profiles
User defined	User defined	User defined

Note, all of the variation controls may have the statistical tolerancing symbol next to the tolerance

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None			
Type of Control	Placement of Control*	Material Condition Modifier	Variation Control
Surface Straightness	b,c	-	<div><div>—</div><div>TOL</div></div>
Flatness	b,c	-	<div><div>▧</div><div>TOL</div></div>
Surface Profile (surface to surface location) (coplanarity)	b	-	<div><div>⌒</div><div>TOL</div></div> n SURFACES

FIG. 8.6






Dimension(s), but not very well defined	-	-	D I M ± T O L
Line Profile (form)	b	-	 T O L
Circularity	b	-	 T O L
Surface Profile (form)	b	-	 T O L
Line Profile (form)	b	-	 T O L
Radius symbol (R) without a center	-	-	R
Radius symbol (R) with center	-	-	R
Surface Profile (form)	b	-	 T O L
Controlled Radius symbol (CR) without a center	-	-	CR
Controlled Radius symbol (CR) with center	-	-	CR
Size dimension and nullify Rule 1	-	-	∅ D I M ± T O L Perfect form at MMC not required.






FIG. 8.7

-	-	-	-
Surface straightness	b	-	<div><div>—</div><div>TOL</div></div>
Circularity	a,b,d	-	<div><div>○</div><div>TOL</div></div>
Line Profile (form)	b	-	<div><div>⤿</div><div>TOL</div></div>
Size dimension	-	-	Ø DIM ± TOL
Cylindricity	a,b,d	-	<div><div>⌀</div><div>TOL</div></div>
Surface Profile (form)	b	-	<div><div>⤿</div><div>TOL</div></div>
-	-	-	-
Axis Straightness	a,d	RFS	<div><div>—</div><div>Ø TOL</div></div>
		MMC	<div><div>—</div><div>Ø TOL Ⓜ</div></div>
		LMC	<div><div>—</div><div>Ø TOL Ⓛ</div></div>
-	-	-	-
-	-	-	-

FIG. 8.8

Size dimension and nullify Rule 1	-	-	$DIM \pm TOL$ Perfect form at MMC not required.
Size dimension	-	-	$DIM \pm TOL$
Size dimension	-	-	$DIM \pm TOL$
Angle dimension	-	-	$DIM \pm TOL$
Median Line Straightness	a,d	RFS	<div><div>—</div><div>TOL</div></div>
		MMC	<div><div>—</div><div>TOLⓂ</div></div>
		LMC	<div><div>—</div><div>TOLⓁ</div></div>
Median Plane Flatness	a,d	RFS	<div><div>▧</div><div>TOL</div></div>
		MMC	<div><div>▧</div><div>TOLⓂ</div></div>
		LMC	<div><div>▧</div><div>TOLⓁ</div></div>
-	-	-	-
Dimension(s), but not very well defined	-	-	$DIM \pm TOL$
Circularity	b	-	<div><div>○</div><div>TOL</div></div>
Line Profile (form)	b	-	<div><div>⤿</div><div>TOL</div></div>

FIG. 8.9

Surface Profile (form)	b	-	<div><div></div><div>TOL</div></div>
Size dimension and nullify Rule 1	b,d	-	<div><div>\varnothing DIM \pm TOL</div><div>Perfect form at MMC not required.</div></div>
Size dimension	-	-	<div><div>\varnothing DIM \pm TOL</div></div>
			<div><div>SRD DIM \pm TOL</div></div>
Circularity	a,b,d	-	<div><div></div><div>TOL</div></div>
-	-	-	
-	-	-	
Line Profile (form)	b	-	<div><div></div><div>TOL</div></div> <div>with all around symbol</div>
Surface Profile (form and surface to surface)	b	-	<div><div></div><div>TOL</div></div> <div>with all around symbol</div>
Surface Profile (form and surface to surface)	b	-	<div><div></div><div>TOL</div></div> <div>ALL OVER</div>
User defined	User defined	User defined	User defined

- * Placement of Control
- a) below or attached to a leader directed callout or dimension

b) leader from control to feature

c) attach to an extension line (planar features only)

d) attached to an extension of the dimension line

FIG. 8.10

Relationship of tolerance zone to Datum Reference Frame

	Oriented		
Dim(s)	Type of Control	Placement of Control*	Material Condition Modifier
None	Parallelism – Line elements	b,c	-
	Perpendicularity – Line elements	b,c	-
	Angularity – Line elements	b,c	-
	Line Profile (orientation)	b	-
None	Parallelism	b,c	-
	Perpendicularity	b,c	-
	Angularity	b,c	-
	Angular dimension	-	-
	Surface Profile (orientation)	b	-
	Angular dimension	-	-
Zero basic shown with extension line	Parallelism	b,c	-

FIG. 8.11

	Perpendicularity	b,c	-
	Angularity	b,c	-
	Surface Profile (orientation and surface to surface) (typically lower tier of composite Profile)	b	-
None	-	-	-
None	Angularity – Line elements	b,c	-
	Line Profile (orientation)	b	-
None	-	-	-
None	Surface Profile (orientation)	b	-
Radius	Line Profile (orientation)	b	-
None	-	-	-
None	Surface Profile (orientation)	b	-
None			
None	-	-	-
None	-	-	-
None	-	-	-

FIG. 8.12

None	Parallelism – Line elements (surface)	b,c	-
None	Perpendicularity – Line elements (surface)	b,c	-
	Angularity – Line elements (surface)	b,c	-
None	Line Profile (orientation)	b	-
None			
None	-	-	-
None	Surface Profile (orientation)	b	-
None			
-	-	-	-
None	-	-	-
-	Parallelism	a,d	RFS
			MMC
			LMC
	Perpendicularity	a,d	RFS
			MMC
			LMC
	Angularity	a,d	RFS
			MMC
			LMC
-	Parallelism	a,d	RFS
			MMC
			LMC
	Perpendicularity	a,d	RFS

FIG. 8.13

	Angularity	a,d	MMC
			LMC
			RFS
			MMC
			LMC
None	-	-	-
None	-	-	-
None	-	-	-
None	-	-	-
None	-	-	-
None	-	-	-
-	Parallelism (center plane)	a,d	RFS
			MMC
			LMC
	Perpendicularity (center plane)	a,d	RFS
			MMC
			LMC
	Angularity (center plane)	a,d	RFS
			MMC
			LMC
None	-	-	-
None	-	-	-
None	Line Profile (orientation)	b	-

FIG. 8.14

None	Surface Profile (orientation)	b	-
None	-	-	-
None	-	-	-
None	-	-	-
			-
			-
None	Line Profile (orientation)	b	-
None	Surface Profile (orientation)	b	-
None	Surface Profile (orientation)	b	-
User defined	User defined	User defined	User defined

FIG. 8.15












Variation Control	Dim(s)	Type of Control	Placement of Control *
 EACH ELEMENT	None	Line Profile	b
 EACH ELEMENT	Right angle (no angle specified)		
 EACH RADIAL ELEMENT	Right angle (no angle specified)		
 EACH ELEMENT	Basic angle(s)		
	None or basic angle(s)		
	None	Surface Profile	b
	Right angle (no angle specified)		
	Basic angle(s)		
	Basic angle(s)	Linear dimension	
Basic angle; vertex located with datum origin symbol	Basic angle(s), vertex located using datum origin symbol		
	None or basic angle(s)		
DIM ± TOL with datum origin symbol	DIM ± TOL with datum origin symbol		
 SIM REQ	None	Surface Profile (with basic dims to DRF)	b

FIG. 8.16









 TOL A	Right angle (no angle specified)		
SIM REQ			
 TOL A	Basic angle(s)		
SIM REQ			
 TOL A	None or basic angle(s)		
-	-	-	-
 TOL A	Basic angle(s)	Line Profile	b
EACH ELEMENT			
 TOL A	Basic angle(s)		
-	-	Circular Runout (locates center of tolerance zone)	a,b,d
 TOL A	Basic angle(s)	Surface Profile	b
 TOL A	Basic radius and basic possibly angle(s)	Line Profile	b
-	-	-	-
 TOL A	Basic radius and possibly basic angle(s)	Surface Profile	b
-	-	-	-
-	-	-	-
-	-	-	-

FIG. 8.17

<div>//TOLA</div> <div>EACH ELEMENT</div>	None	Line Profile	b
<div>⊥TOLA</div>	Right angle (no angle specified)		
<div>∠TOLA</div> <div>EACH ELEMENT</div>	Basic angle(s)		
<div>⌒TOLA</div>	None	Circular Runout (locates center of tolerance zone)	a,b,d
		Line Profile	b
-	-	-	
<div>⌒TOLA</div>	Basic angle(s)	Total Runout (locates center of tolerance zone only)	a,b,d
		Surface Profile	b
-	-	Concentricity	a,b,d
-	-	-	
<div>//TOLA</div>	None	Position	a,d
<div>//TOLⓂA</div>			a,d
<div>//TOLⓁA</div>			a,d
<div>⊥TOLA</div>	Right angle (no angle specified)		
<div>⊥TOLⓂA</div>			
<div>⊥TOLⓁA</div>			
<div>∠TOLA</div>	Basic angle(s)		
<div>∠TOLⓂA</div>			
<div>∠TOLⓁA</div>			
<div>//∅TOLA</div>	None	Position	a,d
<div>//∅TOLⓂA</div>			
<div>//∅TOLⓁA</div>			
<div>⊥∅TOLA</div>	Right angle		

FIG. 8.18

<div><div>⊥</div><div>∅TOL</div><div>Ⓜ</div><div>A</div></div>	(no angle specified)		
<div><div>⊥</div><div>∅TOL</div><div>Ⓛ</div><div>A</div></div>			
<div><div>∠</div><div>∅TOL</div><div>A</div></div>	Basic angle(s)		
<div><div>∠</div><div>∅TOL</div><div>Ⓜ</div><div>A</div></div>			
<div><div>∠</div><div>∅TOL</div><div>Ⓛ</div><div>A</div></div>			
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	Symmetry	a,d
<div><div>//</div><div>TOL</div><div>A</div></div>	None	Position	a,d
<div><div>//</div><div>TOL</div><div>Ⓜ</div><div>A</div></div>			
<div><div>//</div><div>TOL</div><div>Ⓛ</div><div>A</div></div>			
<div><div>⊥</div><div>TOL</div><div>A</div></div>	Right angle (no angle specified)		
<div><div>⊥</div><div>TOL</div><div>Ⓜ</div><div>A</div></div>			
<div><div>⊥</div><div>TOL</div><div>Ⓛ</div><div>A</div></div>			
<div><div>∠</div><div>TOL</div><div>A</div></div>	Basic angle(s)		
<div><div>∠</div><div>TOL</div><div>Ⓜ</div><div>A</div></div>			
<div><div>∠</div><div>TOL</div><div>Ⓛ</div><div>A</div></div>			
-	-	-	-
-	-	Circular Runout (locates center of tolerance zone)	a,b,d
<div><div>⌒</div><div>TOL</div><div>A</div></div>	Basic angle(s)	Line Profile	b

FIG. 8.19

<div><div><div></div></div><div>TOL</div><div>A</div></div>	Basic angle(s)	Surface Profile	b
-	-	-	-
-	-	-	-
-	-	-	-
		Concentricity	a.b.d
		Position	a,d
<div><div><div></div></div><div>TOL</div><div>A</div></div> <div>with all around symbol</div>	Basic angle(s)	Line Profile	b
<div><div><div></div></div><div>TOL</div><div>A</div></div> <div>with all around symbol</div>	Basic angle(s)	Surface Profile	b
<div><div><div></div></div><div>TOL</div><div>A</div></div> <div>ALL OVER</div>	Basic angle(s)	Surface Profile	b
User defined	User defined	User defined	User defined

FIG. 8.20

			User Defined
Located			
Material Condition Modifier	Variation Contorl	Dim(s)	
-	<div><div>⌒</div><div>TOL</div><div>A</div></div>	Basic to DRF	User input
-	<div><div>⌒</div><div>TOL</div><div>A</div></div>	Basic to DRF	User input
	DIM±TOL with datum origin symbol	DIM±TOL without datum origin symbol	User input
-	<div><div>⌒</div><div>TOL</div><div>A</div></div>	Basic to DRF	User input

FIG. 8.21

-	-	-	User input
-	<div><div>⌒</div><div>TOL</div><div>A</div></div>	Basic to DRF	User input
-	<div><div>↗</div><div>TOL</div><div>A</div></div>	Zero (not shown)	User input
-	<div><div>⌒</div><div>TOL</div><div>A</div></div>	Basic to DRF	User input
-	<div><div>⌒</div><div>TOL</div><div>A</div></div>	Basic to DRF	User input
-	-	-	User input
-	<div><div>⌒</div><div>TOL</div><div>A</div></div>	Basic to DRF	User input
-	-	-	User input
-	-	-	User input
-	-	-	User input

FIG. 8.22

-	<div><div><div></div></div>TOL</div> A EACH ELEMENT	Basic to DRF	User input
-	<div><div><div></div></div>TOL</div> A	Zero (not shown)	User input
-	<div><div><div></div></div>TOL</div> A	Basic to DRF	
-			User input
-	<div><div><div></div></div>TOL</div> A	Zero (not shown)	User input
-	<div><div><div></div></div>TOL</div> A	Basic to DRF	
-	<div><div><div></div></div>ØTOL</div> A	Zero (not shown)	User input
-			User input
RFS	<div><div><div></div></div>TOL</div> A	Basic to DRF	User input
MMC	<div><div><div></div></div>TOLⓂ</div> A		
LMC	<div><div><div></div></div>TOLⓁ</div> A		
RFS	<div><div><div></div></div>ØTOL</div> A	Basic to DRF	User input
MMC	<div><div><div></div></div>ØTOLⓂ</div> A		
LMC	<div><div><div></div></div>ØTOLⓁ</div> A		

FIG. 8.23

-	-	-	User input
-	-	-	User input
-	-	-	User input
-	-	-	User input
-	-	-	User input
-	<div><div>≡</div>TOL A</div>	Zero (not shown)	User input
RFS	<div><div>⊕</div>TOL A</div>	Basic to DRF	User input
MMC	<div><div>⊕</div>TOLⓂ A</div>		
LMC	<div><div>⊕</div>TOLⓁ A</div>		
-	-	-	User input
-	<div><div>↗</div>TOL A</div>	Zero (not shown)	User input
-	<div><div>⌒</div>TOL A</div>	Basic to DRF	User input

FIG. 8.24











-	 TOL A	Basic to DRF	User input
-	-	-	User input
-	-	-	User input
-	-	-	User input
-	 SØ TOL A	Zero (not shown)	User input
RFS	 SØ TOL A	Basic to DRF	User input
MMC	 SØ TOL  A		
LMC	 SØ TOL  A		
-	 TOL A with all around symbol	Basic to DRF	User input
-	 TOL A with all around symbol	Basic to DRF	User input
-	 TOL A ALL OVER	Basic to DRF	User input
User defined	User defined	User defined	-

FIG. 8.25